This project has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement nº 604286.
Agenda

2. How? Proposed approach
3. The case study: Pulpwood transportation to a pulp mill in Portugal
4. Computational results
5. Concluding remarks
Wood transportation planning: sequence of spacially distributed decisions....

**Harvesting stands**

- Stand 1
- Stand 2
- Stand 3
- Stand 4

**Volume Availability (m3)**

**Harv. Capacity**

**Multi-Product Assortments Multi-period**

- What is the optimal monthly wood flows (origin-dest-assortment-period)?
- How much trucks?

**Mills**

- Mil 1
- Mil 2

**Production Line**

**Stock Yard 1**

**Production line n**

**Stock Yard s**

**Consumption (TON/daily @production lines)**

**Storing Capacity**

**Truck’s daily route?**

**Truck’s unloading location / time slot in the mill (to avoid queuing)?**
Wood transportation planning: sequence of decisions … at different time scales

Resource allocation (wood flows)

Truck Routing (sequence of trips/truck)

Truck Scheduling (schedule for each truck@location)

Time-slot plan (avoid queuing)

Truck dispatching (next trip for finishing truck)

Planning horizon

years

months

weeks

days

min

Planning period

years

months

weeks

days

min

Closer to execution + uncertainty + info. Needed

e.g. Carlgren et al. 2006; Forsberg et al. 2005; Carlsson and Ronqvist 2007

e.g. Rey, P.A., et al 2009; ...

e.g. El Hachemi, N., 2014; Palmgren, M., et al 2004; ...

e.g. Rönnqvist et al. 1998; Weintraub, A., et al. 1996

We usually assume that execution will go as plan... 
...but it is hardly the case due to uncertainty...

**planning under uncertainty:**

*Predictive planning ≠ Adaptative planning*

Predicts sources of uncertainty and their impact in the outcome of the plan

Robust plans
i.e. outcome not affected by realization of uncertain events

Plan reacts in the face of disruptions in the original plan

Flexible, dynamic plans
new plans are generated whenever a significant disruption is detected by the control, based on information about current execution.

Frequent approaches combine **optimization** (deterministic) with forecasting/simulation (stochastic)

e.g. Laumanns, M. 2011; Shobrys and White (2002)
Reactive (wood) transportation planning:

The goal is to **find high performance plans and schedules** that can cope with the uncertainty and expected events (**predictive mode)**,

**AND**

**During the execution of the plans and schedules, Control/supervise** the impact of unplanned events over the expected plan outcome and whenever possible **react**, Whenever needed, **generate a new schedule** (or even a new plan) for the following operations, based on the current context (**adaptative mode**)
New optimization-simulation approach for reactive wood transportation planning on predictive mode

- **Tactical Planning** (resource allocation)
- **Operational Planning** (routing and scheduling)
- **Supervision & Dispatching** (re-schedule after event)

Mixed-Integer model
Decision variables:
- Heuristic approach (e.g.)
- Dispatching rules implemented in a Discrete event-simulation model

Performance of plan good enough?
- yes
- no

Generate events (uncertainty -> disturbances to plan, breakdowns, delays)

Process (harvesting, transportation, reception)

Supervision: what is the expected performance of the plan considering uncertainty in disturbances and unplanned events
New optimization-simulation approach for reactive wood transportation planning on the adaptative mode

- **Tactical Planning** (resource allocation)
- **Operational Planning** (routing and scheduling)
  - Plans
  - **Process** (harvesting, transportation, reception)
  - **Sensors** (including human)
  - **Supervision & Dispatching** (re-schedule after event)
    - Prepare current status of operations for replan
    - Disturbances (breakdowns, delays)
      - Outcome of plan at end of the day still feasible?
    - yes
    - no
    - alarm
    - Supervision: what is the impact of the event in the plan execution at the end of the day?
Feedback Loop from Simulation to Optimization

Means changing the data set and re-run the same opt-sim models

Predictive mode

- Change parameters affecting the plan’s performance
  - e.g. increase number of trucks
  - e.g. increase supply points
  - e.g. decrease demand@mills

Adaptative mode

- Update status reflecting events until the moment when simulation stops:
  - e.g. remove operations already done and ongoing by all trucks
  - e.g. Update arrival times of trucks in queue
  - e.g. Add unplanned arrivals until that moment

- Increase the length of working hours
The case study: pulpwood transportation in 2 pulp and paper mills in Portugal

2 pulp and paper mills producing a total of 535x10^3 ton/year of woodpulp using 700x10^3 ton maritime pine and 880x10^3 ton eucalypt pulpwood coming from national market; Transportation by road, outsourced.
## Case study characteristics

<table>
<thead>
<tr>
<th>Case study characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of mills</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Total demand</strong></td>
<td>$1780 \times 10^3$ ton per year</td>
</tr>
<tr>
<td><strong>Number or supply locations</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Total availability</strong></td>
<td>$1754 \times 10^3$ ton per year</td>
</tr>
<tr>
<td><strong>Daily deliveries (mill 1)</strong></td>
<td>120: 72 planned + 48 unplanned</td>
</tr>
<tr>
<td><strong>Assortments</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Production Lines</strong></td>
<td>3@mill 1 + 2@mill 2</td>
</tr>
<tr>
<td><strong>Loading and unloading time</strong></td>
<td>15min -&gt; length of the time slots</td>
</tr>
<tr>
<td><strong>Reception time</strong></td>
<td>7min -&gt; length of time slots@gate</td>
</tr>
<tr>
<td><strong>Waiting cost</strong></td>
<td>0.51€/min/truck</td>
</tr>
<tr>
<td><strong>Material handling cost</strong></td>
<td>0.35€/ton</td>
</tr>
<tr>
<td><strong>Cost working extra hours</strong></td>
<td>0.51€/min</td>
</tr>
<tr>
<td><strong>Transportation cost</strong></td>
<td>0.021€/km/ton (full), 0.84 €/km (empty)</td>
</tr>
<tr>
<td><strong>Harvesting cost</strong></td>
<td>10€/ton</td>
</tr>
</tbody>
</table>
Solution Approach: the same for both predictive and adaptative modes

Model 1: Tactical planning
Resource allocation (MILP)

Model 2: Operational planning
Routing and scheduling
(Heuristic approach)

Model 3: Time slot plan
(Revenue Management Approach)

Model 4: Control
Assessment of the current state and impact on plan (DES model)

Start
Baseline plan and schedule

Model 1 the yearly baseline plan, first month goes to operational

Model 2 determines the effective routing and scheduling at a weekly basis

Model 3 time slot allocation at unloading docks inside the mill whenever a truck arrives

Model 4 estimate impact of uncertainty in proposed plan

Need replan?
Yes
Revised schedule

No
End

Uncertainty
Model 1: Tactical planning

Multi site, multi period, multi product wood flow problem

\[ x_{it} = \begin{cases} 1, & \text{if stand } i \text{ is harvested in period } t; \\ 0, & \text{otherwise} \end{cases} \]

\[ y_{ijpt} = \text{Quantity (tons) of assortment } p \text{ transported from stand } i, \text{ to mill } j, \text{ in period } t \]

\[ z_{it} = 1 \text{ if stand } i \text{ started harvesting in period } t; \ 0 \text{ otherwise} \]

Objective: Max profit = revenue – costs

Subjected to:
1. Harvesting at stand \( i \) only once
2. Even harvesting flow across the periods
3. Timber harvested is transported to mills \( j \) in period \( t \)
4. Inventory of assortment \( p \) at the mill \( j \) in period \( t \)
5. Storage capacity of the mill \( j \) in time period \( t \)

MIP formulation -> solved optimally with GUROBI
Model 2: Greedy routing heuristic (inspired in ASICAM)

- Order trucks and jobs to be done
- Select the 1st truck that becomes available
- Assign it to the best remaining job (considering the time slots availability)
- 1 truck -> 1 route
- Update jobs to be done
- All jobs done?
  - no
  - finish
- yes

Model 1: Tactical planning
Resource allocation (MILP)

Model 2: Operational planning
Routing and scheduling (Heuristic approach)

Baseline plan and schedule

Model 3: Time Slot plan
(Revenue Management Approach)

Revised schedule

Model 4: Control
Assessment of the current state and impact on plan (DES)

Need replan?
- Yes
- No

End
Model 3+4: Time slot plan and control

- **Truck arriving**: Check if truck can be assigned to its planned slot
  - yes: Assign truck to its promised slot
  - no: Compute truck’s priority and place it at the queue

- **Time slot starting@line**: Check if exists one truck promised to that slot
  - yes: Assign truck to the time slot -> truck entry the mill
  - no: Select truck from the queue with the best priority

Update trucks waiting time -> entry to stockyard if long wait
Preliminary Results – MILP model

Flow of assortments during 1 year of operation

- The quantity (in tons) of assortments transported from stands to mills in each week
- Mill 0 receives 976,763 tons
- Mill 1 receives 577,944 tons
Preliminary Results – routing and scheduling

One Day

Total waiting costs (euros): 5249.4  
Extra hours cost (euros): 176
Total number of loads: 135   
Number of loads afterhours: 23
Total number of routes: 44 (nº trucks)  
Average N. loads/route: 3

Waiting time in the mill

<table>
<thead>
<tr>
<th>Mill</th>
<th>Waiting time [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill 0</td>
<td>~35min</td>
</tr>
<tr>
<td>Mill 1</td>
<td>~40min</td>
</tr>
</tbody>
</table>

FIFO~90min

Destination ID (Mill line or stockyard) | Number of Loads
---|---
1 | 15
2 | 23
3 | 0
4 | 7
5 | 0
6 | 0
7 | 0
8 | 41
9 | 0
10 | 49
Preliminary Results - Simulation model

RM Queuing in the mill 0

RM Queuing in the mill 1

44 Trucks
Concluding remarks

What?
A new reactive planning concept is proposed for wood transportation planning.

Why?
The proposed concept is a way to deal with uncertainty and generate better plans that make use of information about operations execution, leading to increased performance of the supply chain and reduced transportation costs by better user of the transportation resources and avoiding queuing effects.

How?
The approach is built on a new simulation-optimization approach, inspired in MPC, is expected to reduce the queuing effects and the material handling cost when compared with FIFO (ongoing work).

Next?
Under the framework of FOCUS 7FP project:

✓ Compare results with FIFO
✓ Wrap-up this approach into a collaborative DSS to support the new processes
✓ Integrate with sensors
**FOCUS in a nutshell**

**What?**
7 FP SME-target collaborative RTD project
01-01-2014 to 30-06-2016 (30 months)

**Why?**
Need for integrated processing and control systems for sustainable production in farms and forests.

**How?**
New FOCUS technological platform that combines sensors and sophisticated software solutions for integrated control and planning of the whole forest-based value chain.
7 Work Packages encompassing specification, development of data collection tools as well as control and planning tools, integration; assessment of prototypes into 4 pilot cases. Covering the value chains in Europe of lumber, pulpwood, biomass and cork transformation; from forest planning to industrial processing.
Total budget of ~4M€ (~3M€ EC funding)

**By whom?**
Consortium of 6 SMEs and 6 RTDs from Portugal, Finland, Belgium, Switzerland, Austria and Germany, combining expertise in forestry, sensors, automation and software development.

The goal of FOCUS is to improve sustainability, productivity, and product marketability of forest-based value chains through an innovative technological platform for integrated planning and control of the whole tree-to-product operations, used by forest-producers to industry players.

www.focusnet.eu
References

**Wood transportation planning – Resource allocation**


**Wood transportation planning – truck routing and scheduling**


References


Wood transportation planning – Truck Dispatching


References

**Wood reception at the mill**


**Feedback loop in reactive transportation planning**


Thank you!

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